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TITLE: STATIC PERFORMANCE OF A PULSEJET USING PREHEATED GASOLINE FUEL

AUTHOR: D. S. Perkins

AMERICAN HELICOPTER

DIVISION OF FAIRCHILD ENGINE AND AIRPLANE CORPORATION

MANHATTAN BEACH, CALIF., - COSTA MESA, CALIF., - MESA, ARIZONA

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Research Engineer


**MODEL NO.** **CONTRACT NO.** AF 33(600)-5860, Supplement 5

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# AMERICAN HELICOPTER

DIVISION OF FAIRCHILD ENGINE AND AIRPLANE CORPORATION

MANHATTAN BEACH, CALIF., COSTA MESA, CALIF., - MESA, ARIZONA

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## 1. SUMMARY

Preheating of gasoline fuel was detrimental to static engine performance, with the exception of throttling range, which was extended on both the low and high fuel flow ends of the normal unheated range. Fuel at 145° F showed no significant change in performance over 63° F fuel. Fuel at 250° F and 300° F gave almost identical performance and showed about a 10% loss of thrust at all fuel flows as compared to 63° F fuel. When injected forward of the valves, the heated fuel gave very good specific fuel consumption and without the 10% thrust loss at peak thrust but with an intolerable valve burning problem.

## 2. INTRODUCTION

The purpose of this test program was to determine the effect on pulsejet engine static performance of preheating gasoline fuel.

Since better mixing is considered to result in more rapid combustion, higher combustion chamber peak and effective pressures, and higher thrust, the test program was initiated to determine if preheated fuel would provide increased thrust due to the burning of vaporized fuel with its anticipated better mixing of fuel and air.

Previous investigations by Aerojet and Continental Aviation Companies produced conflicting conclusions as to the effect of preheating fuel on static pulsejet performance. Aerojet's investigation indicated an apparent improvement in performance while Continental's[1] showed a decrease. Continental's test results may be noted in Figure 11. Aerojet's results[2] are quoted as follows:

"On the basis of exploratory tests, there is an apparent gain in thrust of 10 to 15% on gasoline or nitropropane when the fuel is preheated by coiling the tubing around the tailpipe of the motor in coil lengths up to 20 feet. It will be necessary to separate the effect of fuel preheating from that of tailpipe cooling; also experiments with vapor-phase injection are contemplated."

Footnotes:

1. Roepke, F., Summary of Pulsejet Activities, CAE Report No. 382, April 29, 1949.

2. Morris, Brooks T., and Berggren, W. P., Aerojet Engineering Corp., Report No. R-54, September 20, 1945.

## 3. INSTRUMENTATION

Thrust: measured by a Hagen "Thrustorq" null balance meter that measures engine thrust by applying a known pressure against a diaphragm on the opposite side of which is applied the thrust to be measured. Thrust is then found from the thrust-meter calibration curve of balancing pressure versus thrust.

Fuel Flow: measured by Fisher Porter flowmeters with an accuracy of ±1% at 70° F.

Fuel Temperature: measured with an iron-constantan thermocouple connected to a milliammeter that was calibrated with a Leeds and Northrup potentiometer at the start, and again at the conclusion of the tests.

Pressure: measured with a mercury manometer.

Thermocouple Installation: The thermocouple was formed by welding an iron wire and a constantan wire together to form an approximately 1/16" diameter bead. The thermocouple juncture plus forty wire diameters was firmly glass taped to the outside surface of the 1/4" x .030 copper fuel line about 4" before entering the fuel ring.

## 4. TEST EQUIPMENT

A 6.75" pulsejet engine (M102) of 6.6 $^L/_D$ ratio was used during the test with the same valves and fuel injection system as used with unheated gasoline (Figure 6). It was one of the engines originally built for ducted package testing at the Point Mugu Naval Air Missile Test Center.

Three N.R.L. type vane-seating valve boxes were used during the course of testing.

Two heating coils of 9 and 14 feet of 1/4" by .035 aluminum tubing were used both with and without insulation.

## 5. DISCUSSION OF RESULTS

In order to separate tailpipe cooling from engine performance on preheated fuel, a separate 6.75" engine was initially set up to provide fuel heating by means of an internally mounted tailpipe heating coil (Figure 12). The danger and difficulty of starting and operating two engines concurrently, caused a change to a single engine with its own tailpipe heating coil, which could be started and operated remotely.

The heating coil was located on the engine transition and tailpipe (Figure 7) and was tightly or loosely wrapped with different degrees of insulation to provide various fuel outlet temperatures.

Fuel temperature was fairly constant over the middle of the range of each run (Figure 4) and was dependent primarily on the area of tube exposed to conduction and radiation from the hot tailpipe.

The expected higher thrust was not achieved when burning heated fuel. In fact, the opposite trend was observed.

One possible reason for loss of thrust over most of the throttling range when the fuel is preheated is the less thorough mixing of vapor and air that might result from injecting a relatively greater volume of vapor as compared to a smaller volume of liquid gasoline. This large volume of vapor might have difficulty in mixing thoroughly compared to liquid fuel because of poorer penetration into the incoming airstream. Results of injecting the heated fuel forward of the valves and the much better fuel and air mixing resulting therefrom, would substantiate the above reasoning.

Another possible reason is that a colder fuel absorbs heat rapidly from the combustion products of a preceding explosion and tends to quench and contract the remaining combustion products at a rapid rate. This process would give an abrupt chamber pressure decrease that would augment the negative pressure brought about by over-expansion. A more extensive reverse flow up the tailpipe would occur with a resulting higher peak pressure from the following explosion.

At the low end of the throttling range, at around 75 pph. the heated fuel runs showed better thrust than the unheated runs, due possibly to better combustion resulting from better mixing of the vaporized gasoline, as compared to the poor cold-fuel spray that results from running the nozzle used in these tests at the low pressure associated with fuel flow below 90 pph.

The heated fuel runs, with internal fuel injection, consistently showed a wider throttling range than the unheated runs. Higher fuel temperatures gave a wider spread of the range at both the low and high ends, extending from 40 pph to 240 pph with 300° F fuel. The normal unheated fuel range is about 70 to 185 pph.

The first of the above results led to an attempt at better mixing of the fuel and air by using a forward fuel injection system that injects fuel between the valves at a 45° angle with the tube axis, through No. 55 holes drilled in a 1/4 x 0.035 aluminum tube running across the top and bottom ends of the valves (Figure 10).

The results of Runs No. 7, 8, and 9, injecting 265° F fuel through the forward injection system, are shown on the curves. Run No. 7 showed a marked decrease in specific fuel consumption at fuel flows below peak thrust. Peak thrust was the same as unheated, inside injection. The engine during this run became very hot, about 2000° F. The valve box reeds were slightly warped and the valve bumpers started to melt.

Run No. 8 was the second run at the same fuel temperature and showed a substantial decrease in performance from Run No. 7. This second run had been made to obtain the low fuel flow end of Run No. 7, but was found to give a new and lower thrust curve due, evidently, to valve box damage. The specific fuel consumption of this run was still better than any of the previous runs except No. 7.

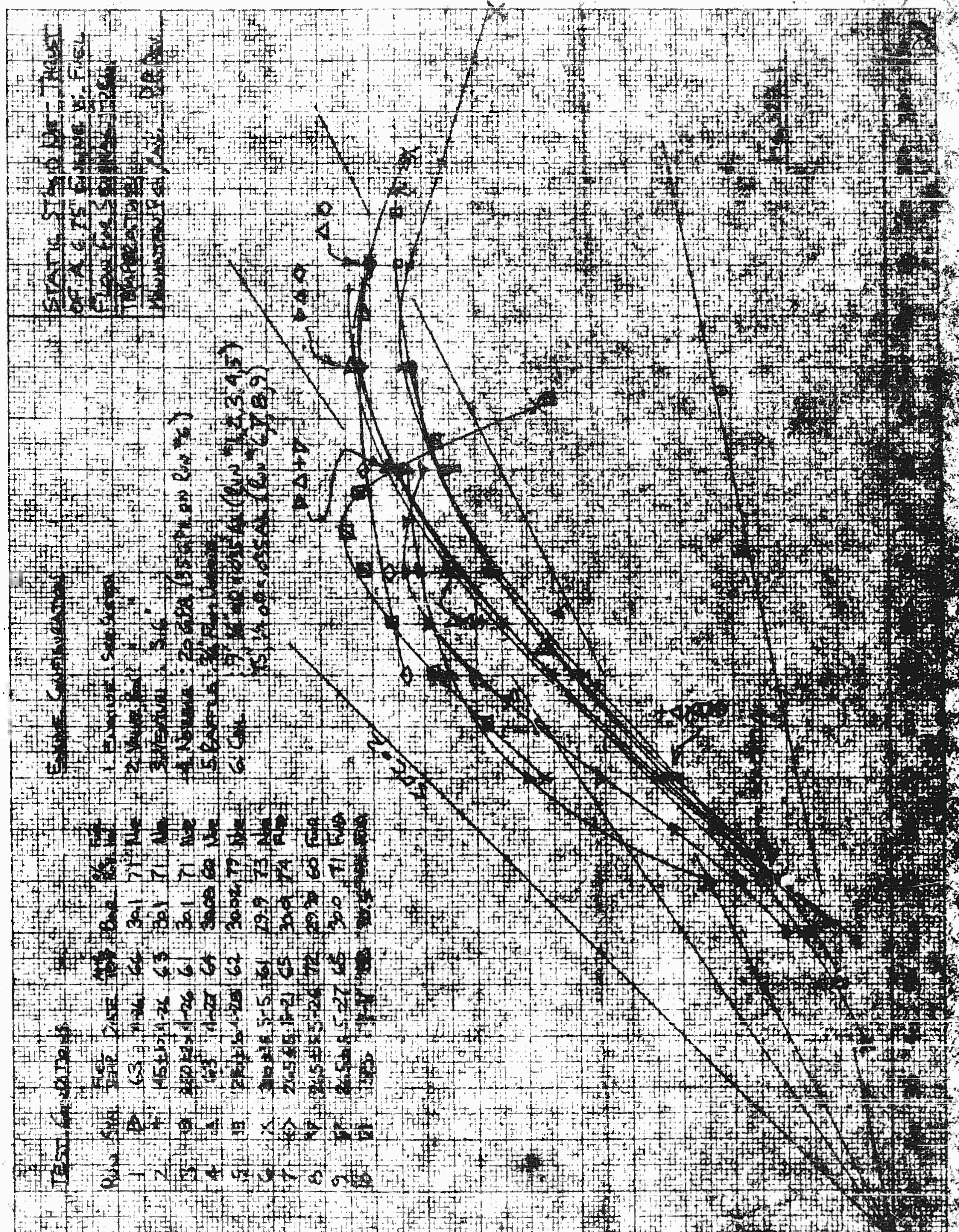
Run No. 9 was made with a new valve box and showed very good specific fuel consumption but peak thrust was below any of the other runs. This new valve box was badly damaged by heat after 5 minutes of running (Figures 8 and 9).

The effect of the colder tailpipe resulting from fuel heating was determined by running the engine on unheated fuel with various fuel flows through the heater coil. This fuel was discarded. No significant effect of tailpipe cooling could be discerned. The length of tailpipe cooled was a maximum of six inches, which was not sufficient to change the performance of the engine.

## 6. CONCLUSIONS

Heating the gasoline made no significant improvements in engine performance over what has already been attained with forward fuel injection with unheated fuel. There is a decrease in static engine performance when the fuel is heated and injected through a standard fuel nozzle.

With forward heated fuel injection, the performance is similar to unheated forward fuel, but with an intolerable valve damage problem.


359-14 KEUFFEL & ESSER CO.
Millimeters, 5 mm. lines accented, cm. lines heavy.
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359-14 KEUFFEL & ESSER CO.
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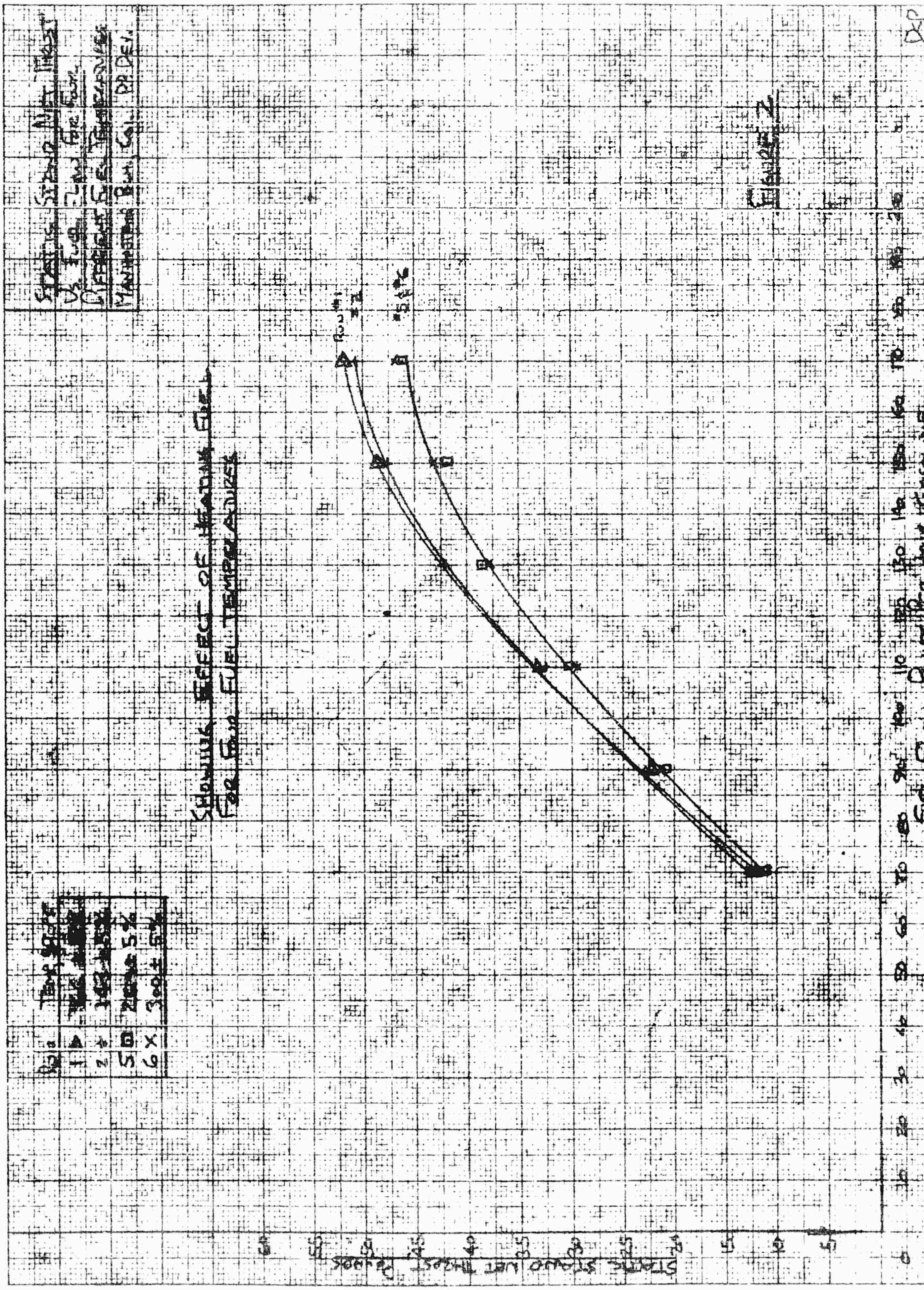


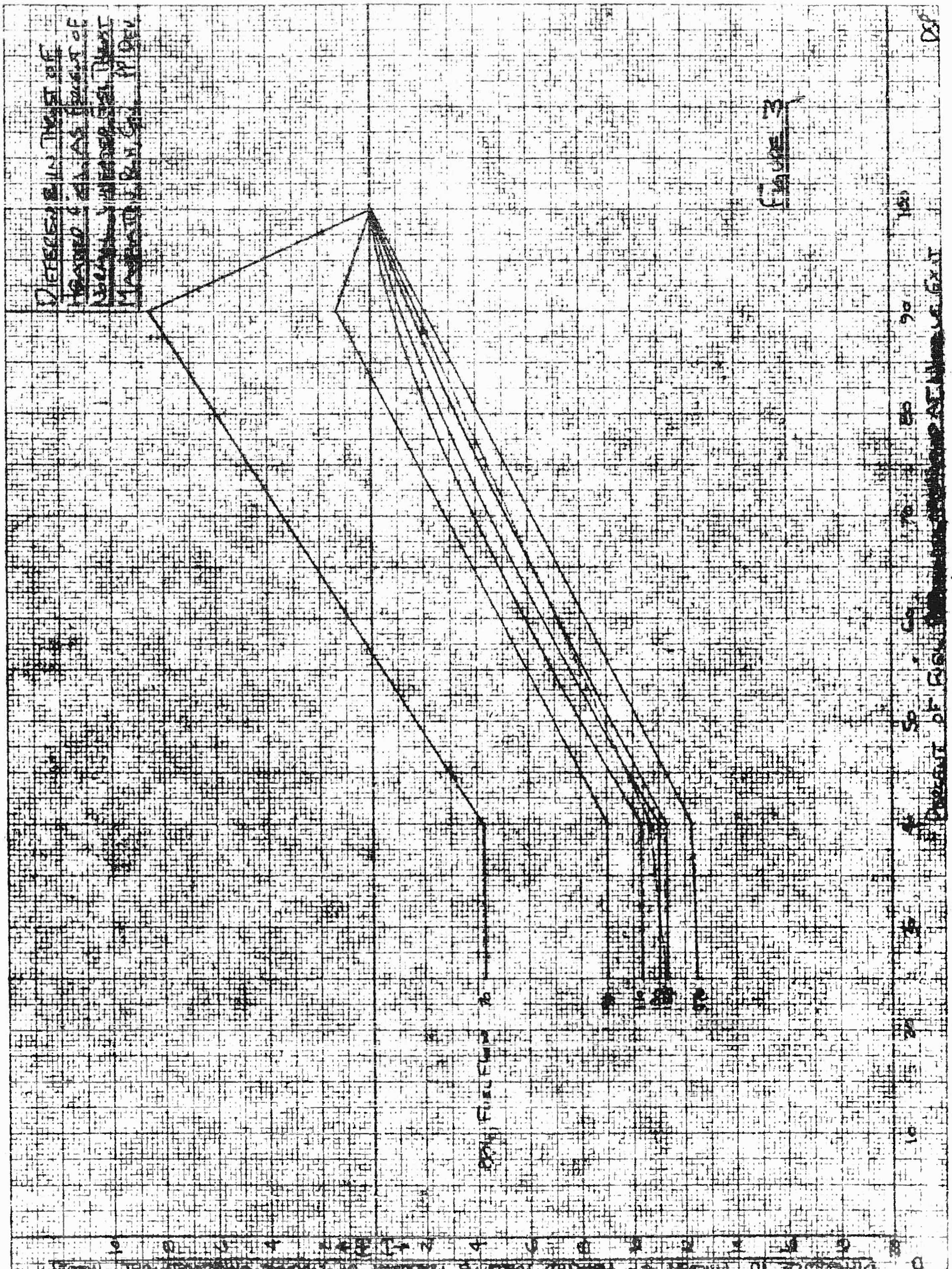


Figure 3

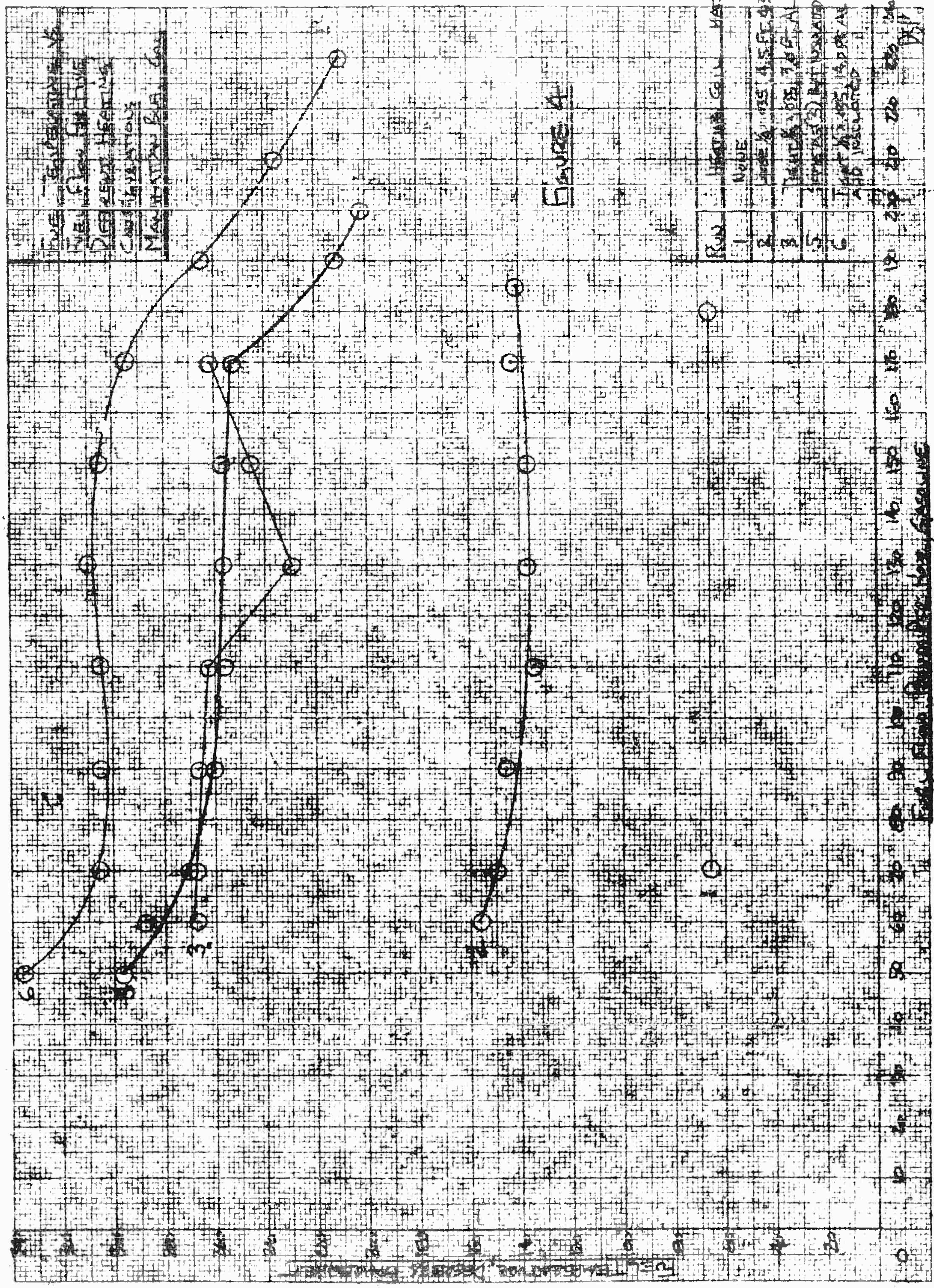
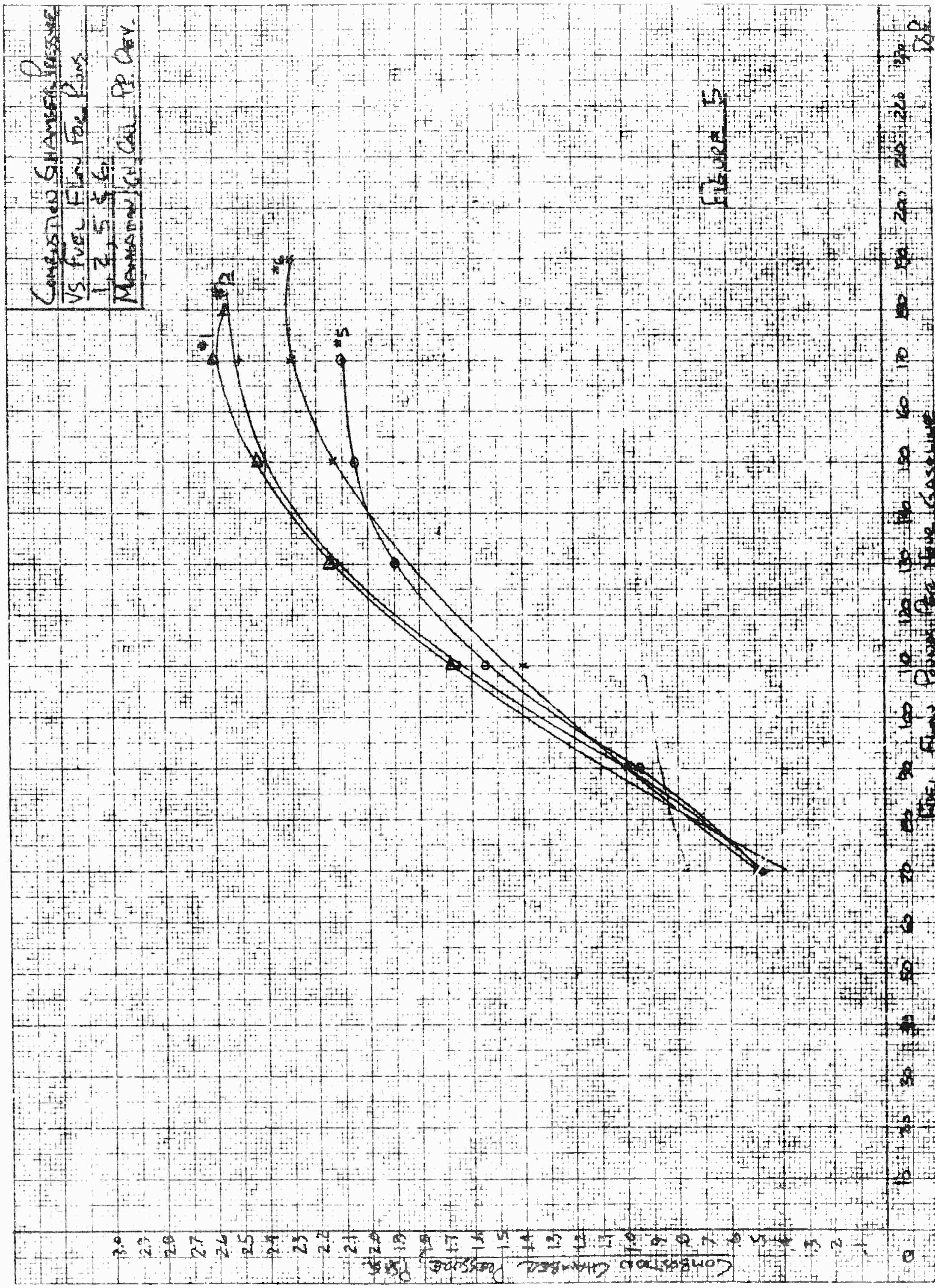
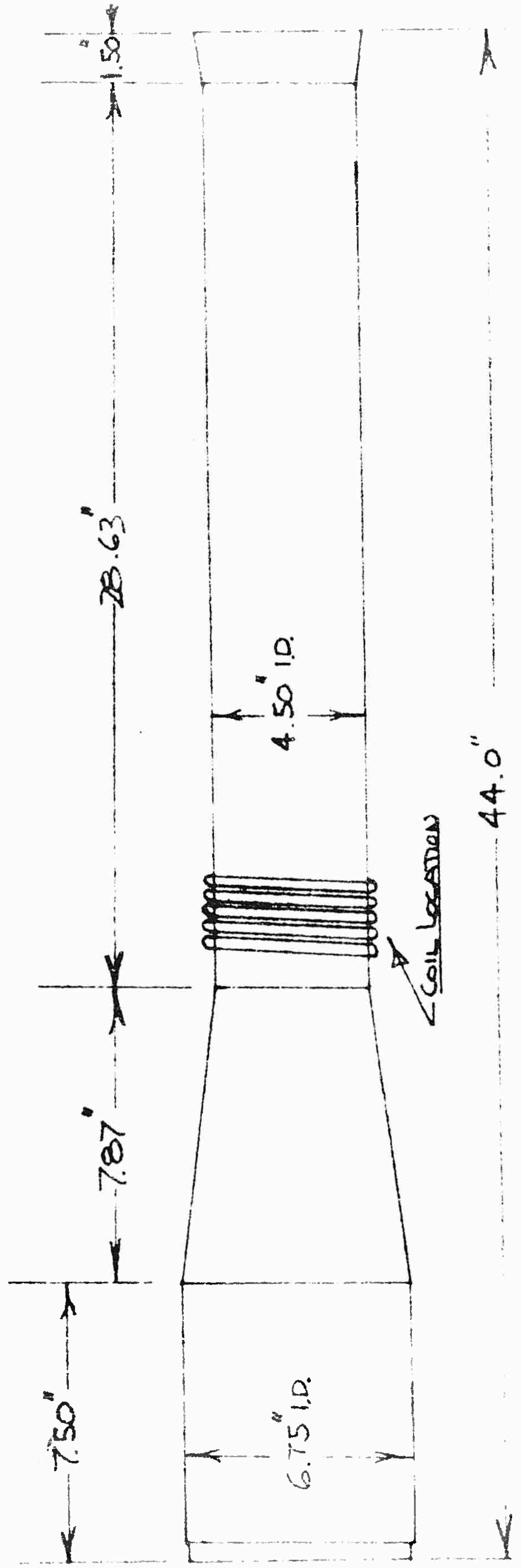
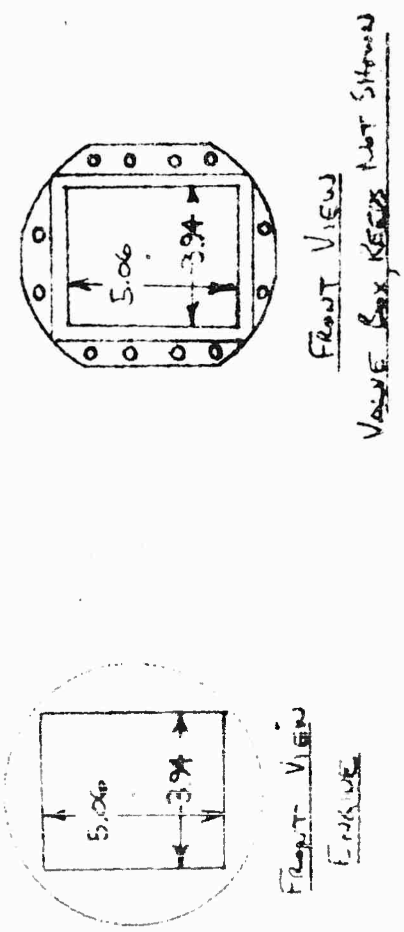


Figure 4
Run
Heating Coil Mat.
1
None
2
3
5
6
Fuel Flow, Pounds Per Hour, Gasoline






SKETCH SHOWING 6.75" ENGINE, AND
FRONT VIEW WITH AND WITHOUT
VALVE BOX

FIGURE 6

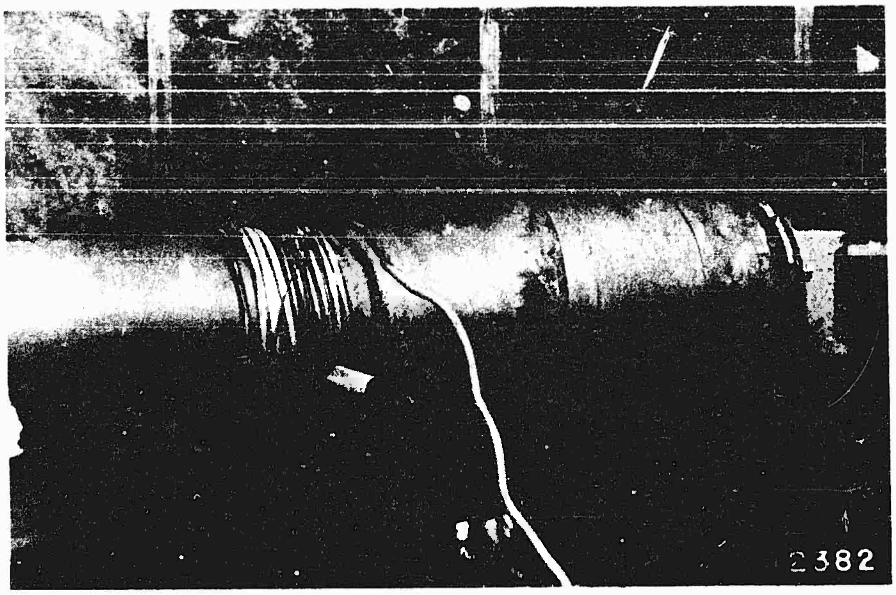



Figure 7

1/4" O.D. Aluminum Heating Coil
Wrapped Around Pulsejet Tailpipe

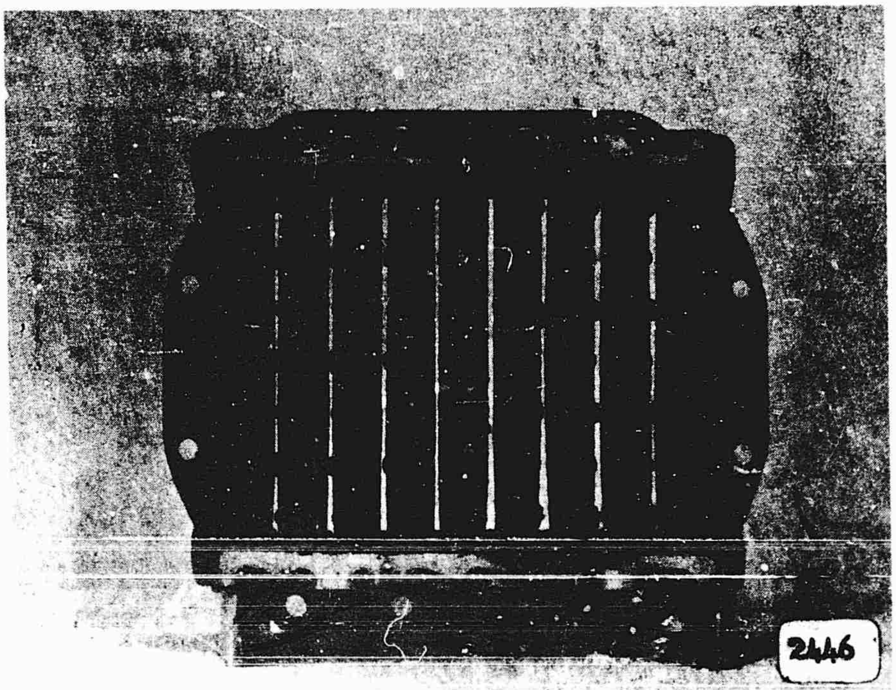



Figure 8

Burned Bumper and Reeds Resulting
From Injecting Heated Gasoline
Through the Valves - Front View

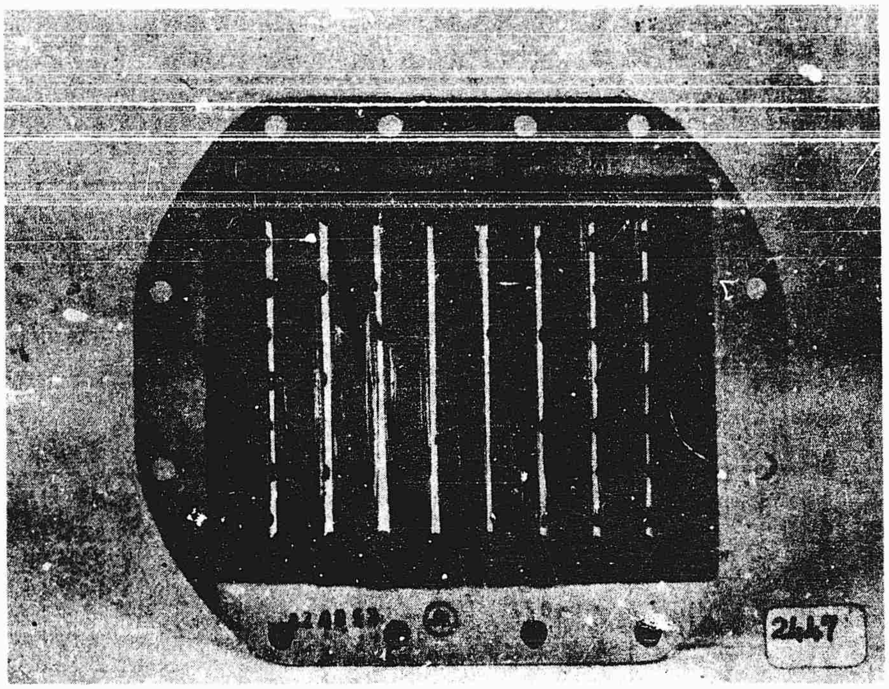



Figure 9

Valve Damage Resulting From Forward
Injection of Preheated Gasoline.
Same Valve Box as Figure 8 - Rear View

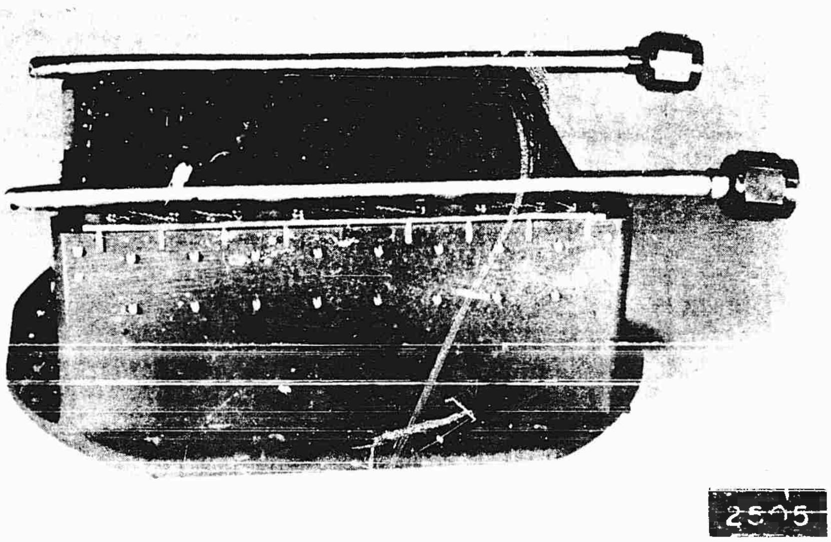


Figure 10

Configuration Used For Forward
Fuel Injection of the Preheated
Gasoline

From Continental Aviation & Engrg.
CAE Report No. 382
Page 59
CAE Curve No. 4386

**EFFECT OF PRE-HEATED FUEL ON PERFORMANCE OF P-11-3 PULSE JET ENGINE**

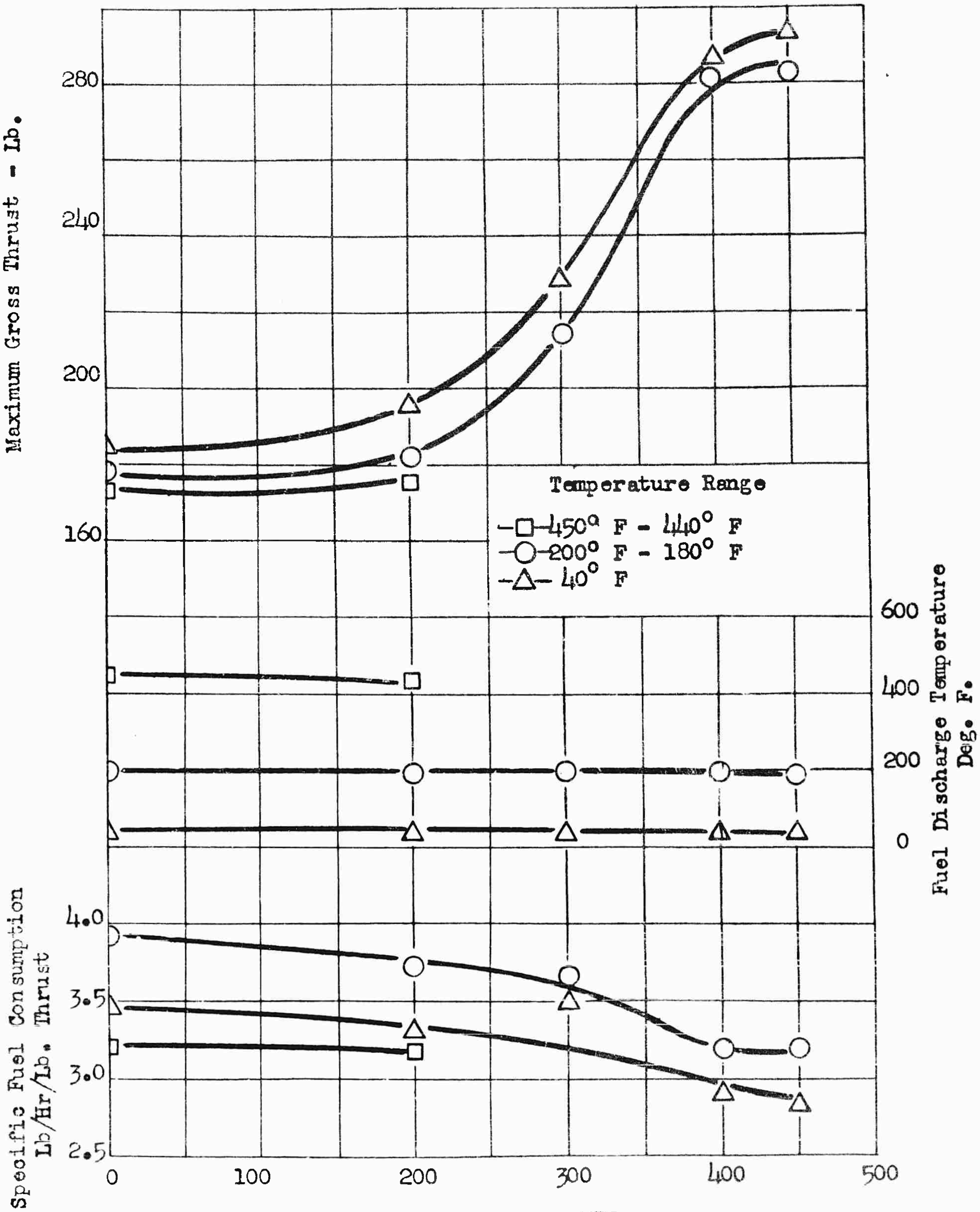



Figure 11 Indicated Air Speed - MPH

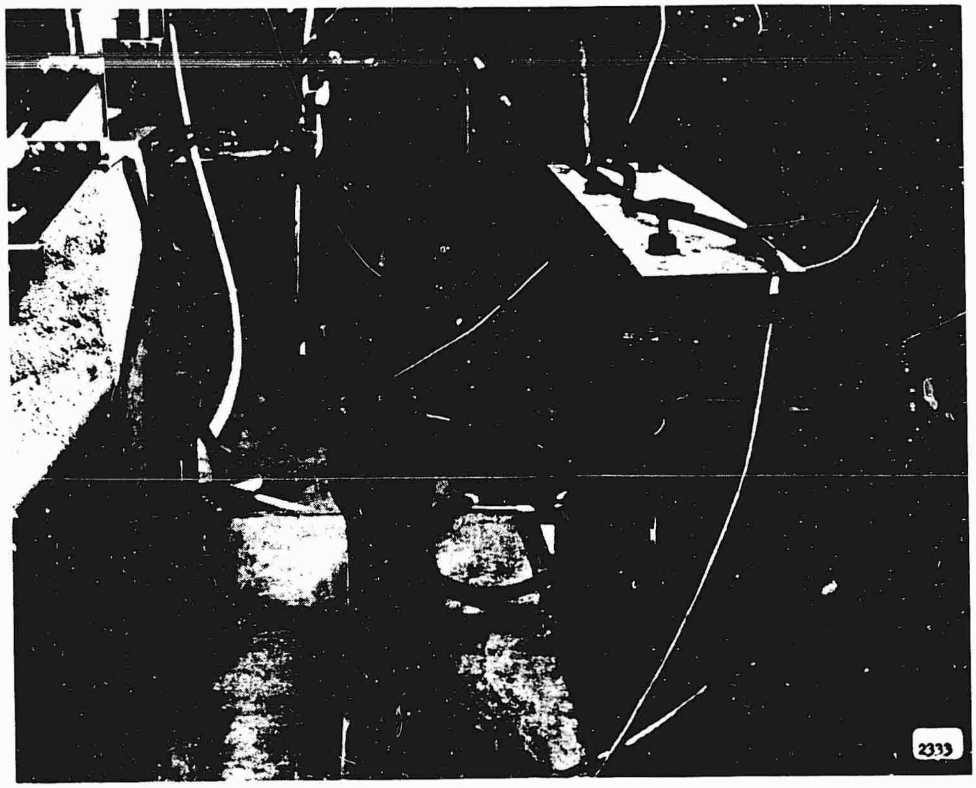


Figure 12

6.75" Engine Initially Used For Fuel Preheating. Test Engine is on the Static Stand at Left